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EXHAUST GAS SCREW TYPE SUPERCHARGER
[Abgasschraubenlader]

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Today, exhaust gas turbo-supercharging of an internal combustion engine is the state of the art.

However, exhaust gas turbochargers (ATL) and mechanically driven turbochargers (TL) have an array of problems:

The operational limit is set by the surge limit of the compressor;

Very high rotational speeds are required, namely, for radial-flow wheels;

At smaller engine capacities, only modest efficiencies are achieved, above all in the partial load range;

Separate charge air coolers at higher boost pressure rates increase the price of the supercharger unit and increase the structural volume;

An operating characteristic curve which climbs precipitously with the engine speed, which, for high pressure supercharging and high engine speeds, has an unfavorable effect on turning moment behavior of the internal combustion engine, can only be improved by costly measures (impulse supercharging, blowing clear of exhaust gases or air, boost pressure control).

Therefore, an exhaust gas screw type supercharger (ASL) shall be proposed which does not have such problems:

- No surge limit as a displacement machine;
- Low peripheral speeds ($15 \div 60 \text{ ms}^{-1}$);
- High efficiencies even for low engine outputs;
- High partial load efficiencies;
- Waiving of charge air cooler at "normal" boost pressure rates; for very high boost pressure rates (at $\pi = 5$) modest cooling capacities are required;
- An operating characteristic curve which runs level with the engine speed and is only slightly dependent on the engine speed;

- High acceleration behavior by means of comparatively small polar mass moment of inertia.

The exhaust gas screw type supercharger comprises according to the invention a screw type supercharger (SL) for charging the internal combustion engine and a directly or indirectly coupled adiabatic screw type motor (SM) driven by the exhaust gases of the internal combustion engine.

The screw type supercharger, a screw type compressor preferably comprising coated rotors, can run dry (adiabatically). With injection cooling, by changing the flow of the cooling fluid mass, the average polytrophic exponent can be adapted to the operating conditions, for example, in order to facilitate ignition. For a diesel engine, diesel fuel is selected as the injection fluid, which is preheated in the screw type supercharger and is injected in the engine combustion chamber. For a boost pressure rate of $\pi_L = 3.5$, the adiabatic turbo compressor reaches, according to the efficiency and entry temperature, emergence temperatures of $t_2 = 170 \div 220^\circ\text{C}$. At the emergence of the screw type supercharger, temperatures of $t_2 < 70^\circ\text{C}$ can be achieved for the same pressure rate. An oil cooler is necessary only if the screw type supercharger is to be driven with uncoated rotors, in a quasi-conventional manner. According to the set-up of the ASL, start-up valves and a mechanical separation of the entire supercharger unit from the engine can be provided for (Figure 5, Figure 8), in order to facilitate or even to enable the starting process.

The screw type motor features dry operation (coated or uncoated). A bypass valve can be allocated thereto in order to circumvent the expansion process during the start-up process of the internal combustion engine.

In order to optimize efficiency, for a given engine speed, either the rotor diameter or the rotor speed must be adapted by means of an additional reduction stage.

Figure 1 shows a main schematic. Therein,

- 1 Signifies entry into the screw type supercharger (SL)

- 2 Signifies emergence from the screw type supercharger
- 3 Signifies entry into the screw type motor (SM)
- 4 Signifies emergence from the screw type motor
- E Signifies entry into the internal combustion engine (VM)
- A Signifies emergence from the internal combustion engine

There are various possibilities for executing an exhaust gas screw type supercharger. For a free-running exhaust gas screw type supercharger (Figure 2) there is no mechanical coupling of the ASL with the VM. Engine speed and boost pressure are not dedicated directly to each other.

As for the vehicle gas turbine, the ASL operates as a "gas producer"; as for an exhaust gas turbocharger, an effective function cannot be extracted from the supercharger unit.

The henceforth higher internal combustion engine emergence pressure P_A calls for larger valve overlaps. The engine operating curve, for a decreasing rotational speed will be at a relatively high boost pressure level, according to the displacement device characteristics of the supercharger. The acceleration behavior decreases relative to other set-ups cited in the following text, since the coupling brings about a temporal phase shift only by means of the operational fluid. For the starting process the start-up valves 1 and 2 are opened, with the supercharger thereby being by-passed. When the exhaust gas temperature then rises, the valve 1 is closed initially in order to accelerate the supercharger unit; then, the valve 2 is closed in order to initiate supercharging. An oil cooler is required only in conventional supercharger operation, that is, without fuel injection cooling.

In Figure 3, the working surface of an exhaust gas driven screw type motor is represented.

First the expansion of exhaust gas occurs from the pressure P_Z at the expansion point in the cylinder to the entry pressure P_3 of the screw type expander. Added to this is the expansion in the screw type motor to the counter pressure P_4 .

Figure 4 characterizes, with the aid of the curves of the exhaust gas screw type supercharger (= solid line) and of an exhaust gas turbocharger (= dashed line), the course of the expansion pressure rate P_3/P_4 as a function of the compression pressure rate P_2/P_1 at the zero effective work of the ASL and ATL. Parameter is the exhaust gas temperature at the commencement of expansion. Thus, for an average exhaust gas temperature of 700°C , the ATK requires a turbine pressure rate of $P_3/P_4 = 1.95$, the ASL a screw type motor pressure rate of $P_3/P_4 = 1.75$.

A mechanically coupled exhaust gas screw type supercharger is represented in Figure 5.

Both supercharger parts, SL and SM are coupled mechanically to the engine crankshaft. For the SM, the peripheral speed of the design can be achieved directly by means of the tooth count of the output pinion, without additional reduction stage.

The starting process can also be carried out without SL start-up valve. There are two set-up possibilities for the starting process:

1. In order to achieve a sufficiently high SL pressure rate and an adequate exhaust gas temperature, the SM takes its starting capacity from the combustion crankshaft.
2. The SM is mechanically uncoupled from the internal combustion engine, the exhaust gases reach the atmosphere through the SM start-up valve (V2).

Figure 6 clarifies the conditions under which the ASL can transmit an effective work to the internal combustion engine (prefix agreement: the specific effective work applied to the ASL is counted positive (+ w_N), the specific effective work rendered by the ASL is counted negative (- w_N !)). The rates of the free-running ASL are represented on the X-coordinate.

Figure 7 shows the idealized p-V diagram of the boost changeover of a 4 stroke engine with retention of the exhaust gases up to the expansion pressure in the cylinder (z), that is, $p_3 = p_z$.

A complete retention of the exhaust gases up to expansion pressure admittedly supplies a theoretically complete recovery of the interpolar work (w_{RZ}), $w_{RZ} = A(z, 4, 4', 3') - A(z, 0, 4', 3')$, if the conversion efficiency is assumed as 1; however, the engine cylinder then suffers under insufficient boost change of the residual gases.

A variant to the aforementioned set-up, the mechanically coupled screw type motor is indicated in Figure 8. Here the ASL remains as a unit.

Additional control by means of direct dependence on engine speed is not necessary.

For the starting process, there are also two set-up possibilities here:

1. The entire charging group is mechanically separate from the engine. The open start-up valves V1 and V2 permit a "normal" boost change of the engine (operation without boost). In supercharger operation, said valves are closed and the pinion of the charging unit engages with the crankshaft gear (shiftable operation).
2. For non-shiftable operation, the internal combustion engine must prepare the idling capacity of the charging group. Fresh air and exhaust gas then flow through the two open bypass valves V34 and V12 (Figure 9).

Claims

1. Exhaust gas supercharger for charging an internal combustion engine, characterized in that a screw type compressor (screw type supercharger) for charging an internal combustion engine is driven by a screw type motor which is driven with the exhaust gases of said internal combustion engine.
2. Exhaust gas supercharger according to Claim 1, characterized in that the screw type compressor (screw type supercharger) is internally cooled.

3. Exhaust gas supercharger according to Claim 2, characterized in that internal cooling is carried out by injecting a fluid in the screw type compressor (screw type supercharger).
4. Exhaust gas supercharger according to Claim 3, characterized in that fuel is used as the injection fluid.
5. Exhaust gas supercharger according to Claim 4, characterized in that the injected fuel, after being preheated in the compression chamber of the screw type compressor (screw type supercharger) is supplied to the combustion chamber of the internal combustion engine.
6. Exhaust gas supercharger according to Claims 3-5, characterized in that the average polytropic exponent of compression in the screw type compressor (screw type supercharger) can be adapted to the operating conditions of the internal combustion engine by varying the cooling mass stream.
7. Exhaust gas supercharger according to Claim 1-6, characterized in that a gearing is arranged between the screw type compressor (screw type supercharger) and the screw type motor.
8. Exhaust gas supercharger according to Claim 1-7, characterized in that the rotors of the screw type motor are coated.
9. Exhaust gas supercharger according to Claim 1-8, characterized in that the screw type compressor (screw type supercharger) is carried out to be free-running with the screw type motor, i.e., is not mechanically coupled with the internal combustion engine.
10. Exhaust gas supercharger according to Claim 1-8, characterized in that the exhaust gas screw type supercharger is mechanically coupled with the shaft of the internal combustion engine.
11. Exhaust gas supercharger according to Claim 10, characterized in that during start-up the entire supercharger group is mechanically separated from the internal combustion engine and the screw type compressor (screw type supercharger) and screw type motor are bypassed by means of start-up valves.

12. Exhaust gas supercharger according to Claims 10 and 11, characterized in that a hydraulic coupling is provided between the exhaust gas screw type supercharger and the internal combustion engine.

Fig. 1

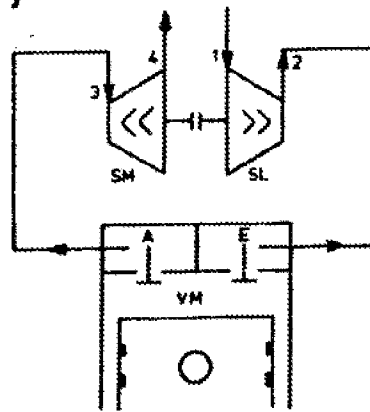


Fig. 2

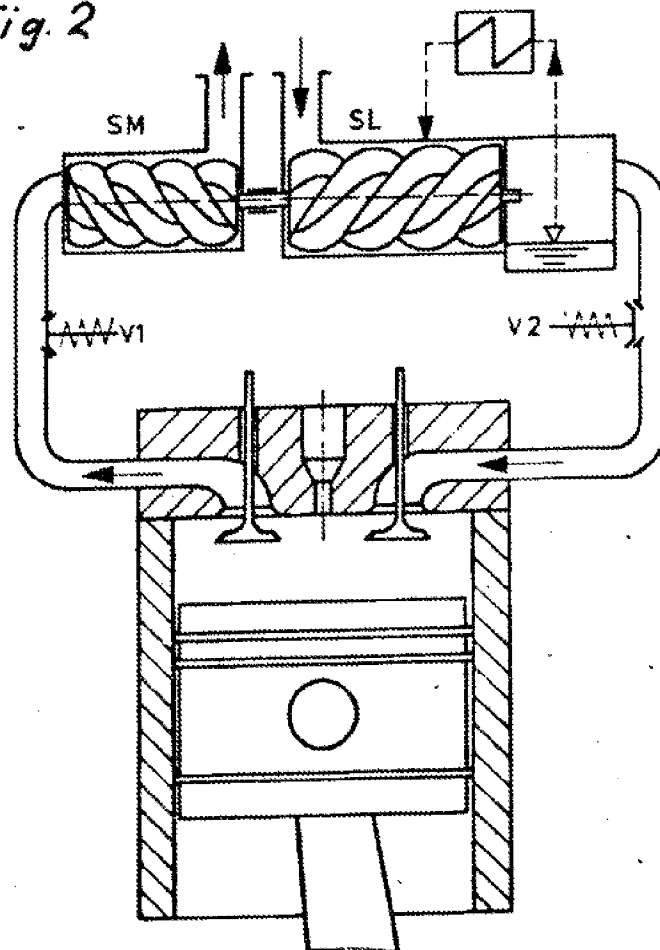


Fig. 3

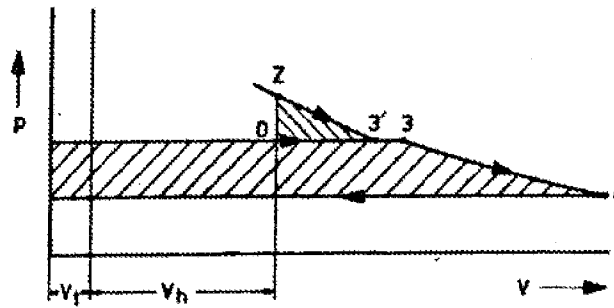


Fig. 4

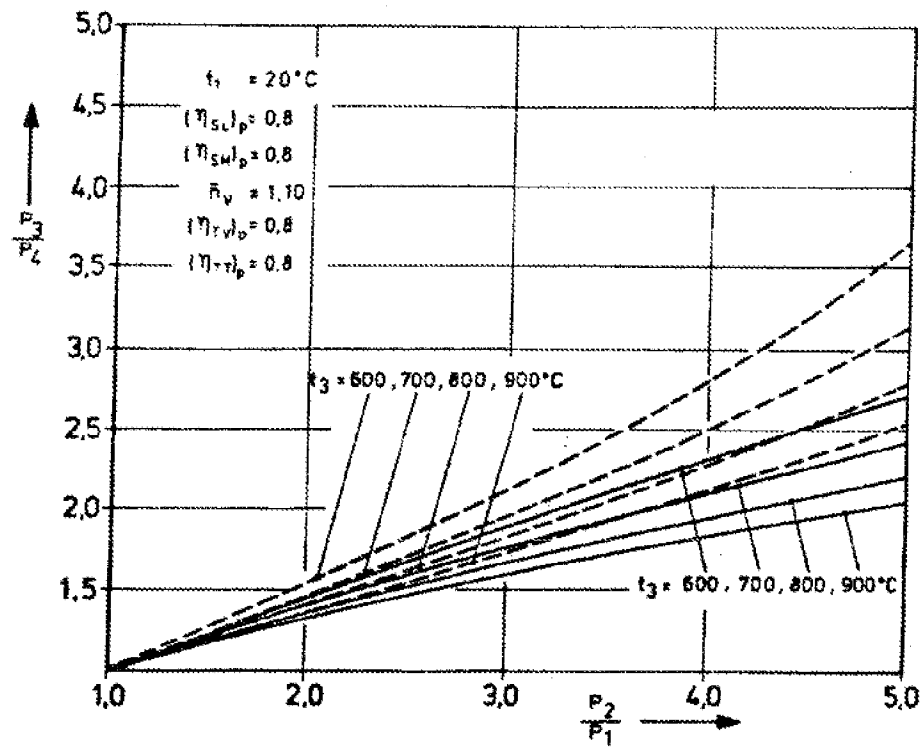


Fig. 5

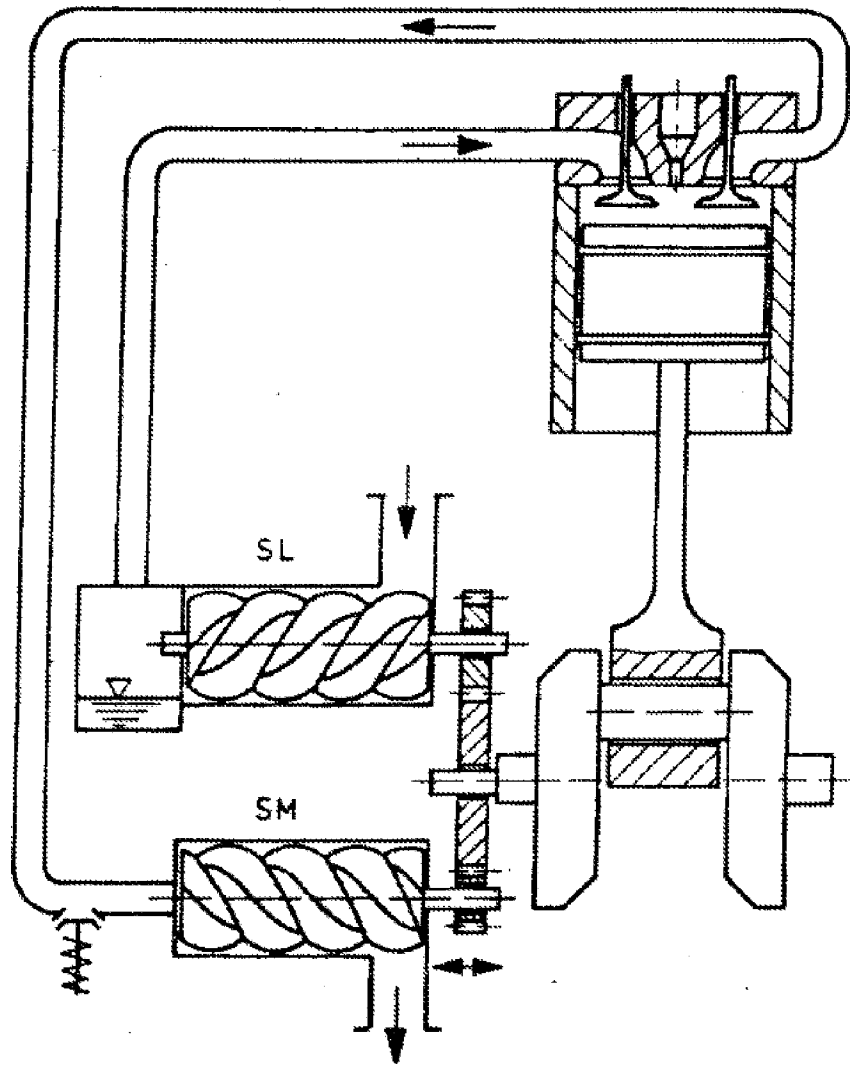
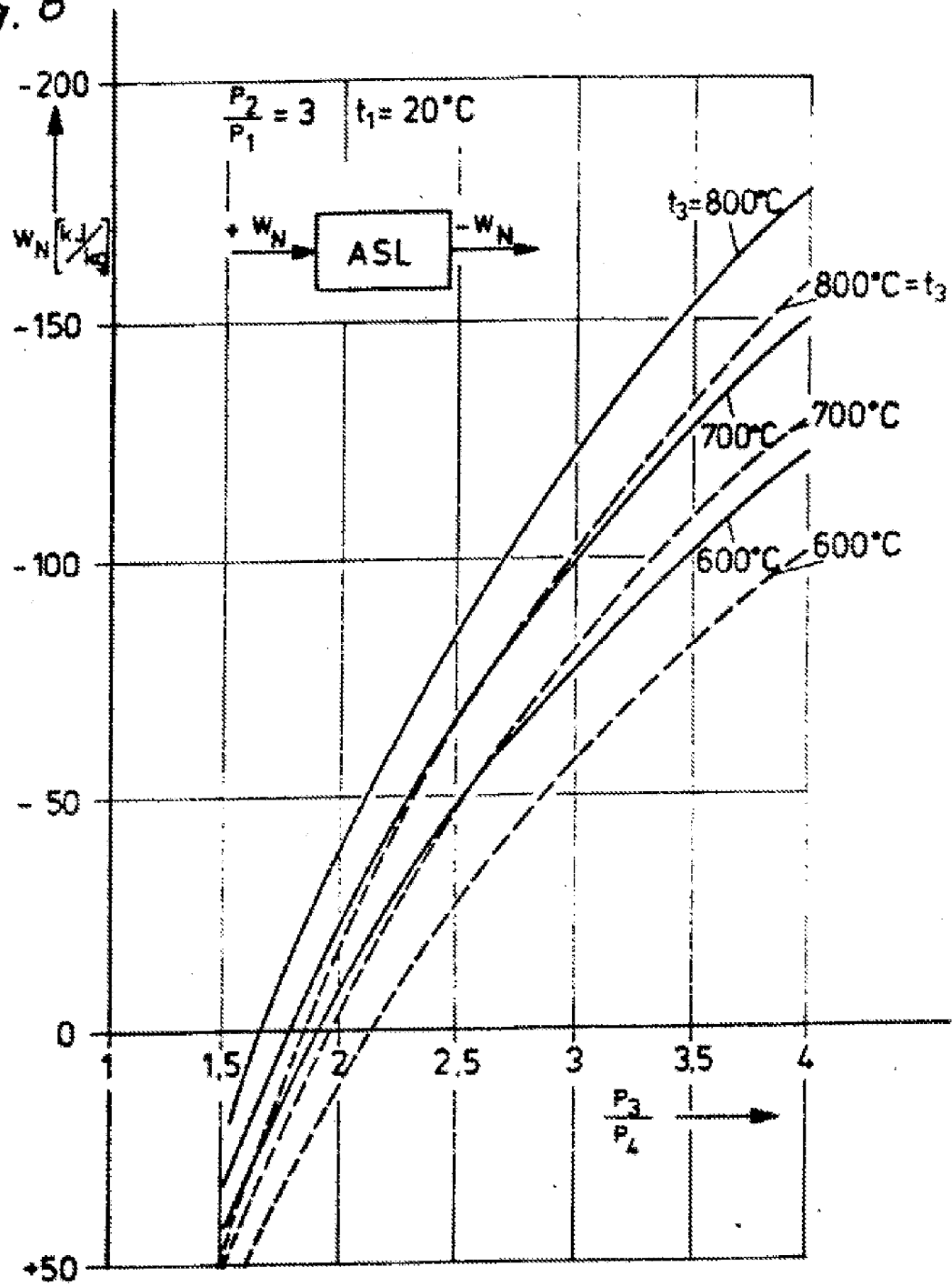


Fig. 6



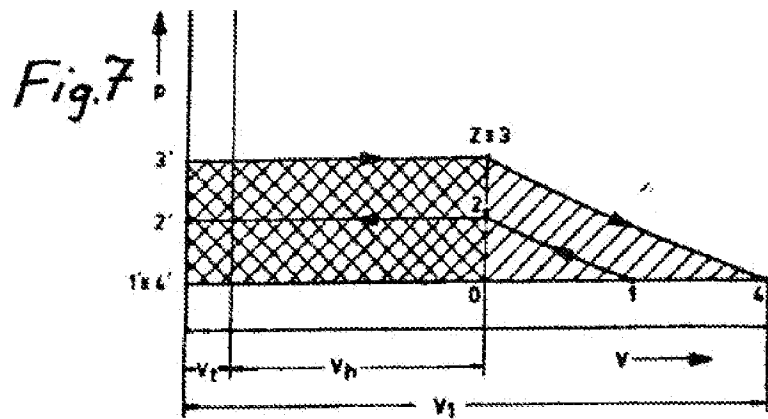


Fig. 8

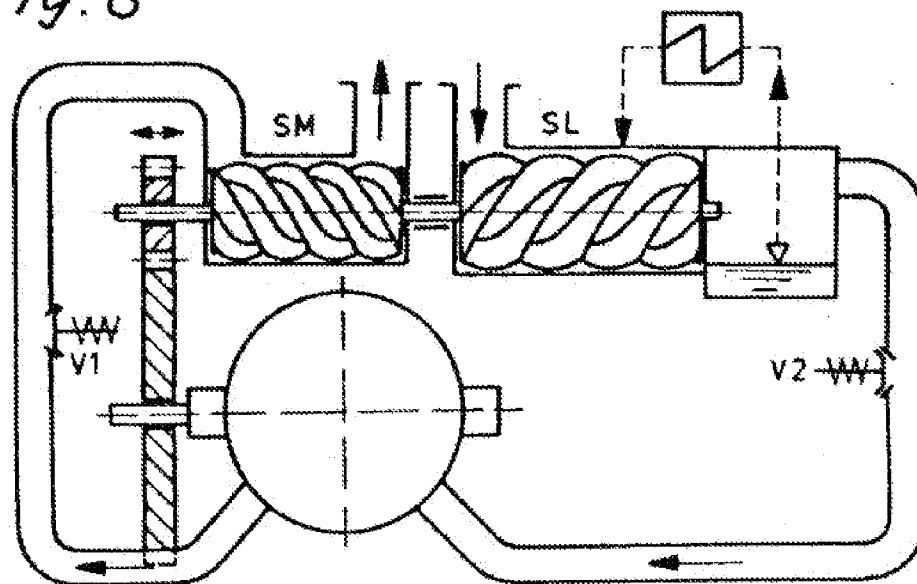
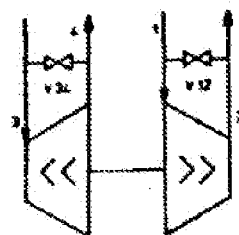


Fig. 9



EUROPEAN SEARCH REPORT

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|--|---|---|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl. ⁴) |
| X | DE-A-2 930 124 (WIESER) * Page 12, Line 13 – Page 13, Line 20; Figure 1 * | 1 | F 02 B 37/00 F 02 B 33/36 |
| Y | --- | 2-5 | |
| A | | 10 | |
| Y | DE-A-2 814 919 (BAUER) * Page 8, Line 19 – Page 9, Line 1; Page 11, Line 14 – Page 12, Line 14; Figure 1 * | 2, 3 | |
| Y | DE-C- 698 476 (ARGUS) * Page 1, Line 25-58; Figure * | 4, 5 | TECHNICAL FIELDS SEARCHED (Int. Cl. ⁴) |
| A | FR-A-2 286 279 (HONDA) * Page 4, Line 4 – Page 5, Line 35; figures 1,2 * | 1,4,5,10 | F 02 B F 04 C F 01 C |
| The present search report has been drawn up for all claims. | | | |
| Place of search The Hague | | Date of completion of the search September 2, 1987 | Examiner M. Hakhverdi |
| CATEGORY OF CITED DOCUMENTS X: Particularly relevant if taken alone. Y: Particularly relevant if combined with another document of the same category. A: Technological background. O: Non-written disclosure. P: Intermediate document. T: Theory or principle underlying the invention. E: Earlier patent document, but published on, or after the filing date. D: Document cited in the application. L: Document cited for other reasons. &: Member of the same patent family, corresponding document. | | | |